Adaptive Intelligent Agents: Human–Computer Collaboration in Command and Control Application Environments

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ABSTRACT

In the past decade, intelligent agents have proven to be of interest in many important application areas, such as electronic commerce on the Internet, the control of space probes on missions to the outer planets, the design of user interfaces, and military mission planning and execution operations involving decision-making and co-ordination functions—collectively known as command and control (C^2). C^2 application environments are dynamic and non-deterministic; thus, there are unique challenges involved in incorporating intelligent-agent technology within them. Decision-makers are required to assess and solve a variety of problems as quickly as possible, at times without adequate resources. The incorporation of agent technology into C^2 applications offers great benefit in the form of human–computer collaboration and provides decision-makers with assistance in carrying out their mission-related activities. This paper presents some suggestions on the types of tasks best suited to agents used in C^2 application environments and discusses the challenges involved in using agent technology within C^2 application environments.

INTRODUCTION

Command and control (C^2) application environments are characterized by their uncertainty and dynamism. This presents several challenges in implementing agent technology into them. Agents must be able to adapt to the changing circumstances and events of a military contingency, which means they must remain somewhat autonomous if they are to effectively assist human decision-makers in accomplishing their C^2 mission-related activities. Agents must possess enough autonomy to behave proactively in order to be of maximum benefit in a human–computer partnership. While this is true, the abilities of human decision-makers in the areas of conceptualization, abstraction, and creativity [1] far surpass their agent counterparts, whose strengths lie in computational speed, parallelism, accuracy, and data assimilation and management. Given these facts, this paper attempts to answer the following questions: (1) How can we effectively use agents to assist military decision-makers? (2) To what level can agents remain truly autonomous when humans must be kept in the loop? (3) Are there certain tasks that are better suited for agents to perform in C^2 application domains?

DEFINITIONS

This section defines some of the terms that will be used throughout this paper.

Autonomous Agents: Software and robotic entities capable of independent action in open, unpredictable environments. Autonomy has most often been defined as freedom from human intervention, oversight, or control [2].

Software Agents: Autonomous software entities that perform tasks on behalf of a user or another agent. Autonomous entities can assist users when performing their operations, collaborate with each other to jointly solve different problems, and answer users' needs [3].

Adaptive Agents: Webster's dictionary [4] defines "adapt" as the capability "to adjust (oneself) to new or changed circumstances." An adaptive agent can acquire knowledge (learn) and adapt (adjust) its behavior accordingly.

Multi-agent Systems: Multi-agent systems may be regarded as a group of intelligent entities called agents, interacting with one another to

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14. ABSTRACT
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collectively achieve their goals [5]. Multi-agent systems implement distributed problem-solving, which provides many advantages including fast, parallel computing and increased fault tolerance [6].

Command and Control: Decision-making and coordination activities performed by military decision-makers during a contingency.

Human–Computer Collaboration: The ability of humans and computers to work together to solve problems. Specifically, while engaged in problem-solving and decision-making, humans contribute the ability to draw upon personal experience and intuition, and autonomous agents assist humans by providing superior speed, accuracy, and computational power.

AUTONOMOUS AGENTS IN C^2 APPLICATION ENVIRONMENTS

This section is divided into two parts. The first part gives an overview of current C^2 operations. The second part presents a domain example describing possible tasks that could be assigned to agents acting autonomously to assist decision-makers in accomplishing their mission-related activities.

C^2 Overview

The need for automating methods of accomplishing military C^2 activities is of utmost importance in today's military mission planning and execution operations. As previously defined, C^2 activities are those decision-making and coordination activities performed by military decision-makers. In combat, effective C^2 and success in battle requires commanders to develop associations and thought patterns. During a contingency, military commanders and their staffs must make timely and effective decisions under pressure. They often spend too much time manipulating information systems to filter data into meaningful information and performing routine tasks to assess the situation. It takes years of training and experience to develop the required skills to manage the pre-planning and subsequent engagement during a tactical encounter. Thus, even with advances in the area of intelligent systems, in C^2 environments humans must be kept in the "loop." Currently, most military C^2 activities performed by decision-makers are accomplished via paper and voice circuits. Toward this end, technology based on intelligent agents acting autonomously to perform user-specified tasks offers potential for automating and speeding up many of these time-critical activities. The next section focuses on human–computer collaboration within the context of a specific C^2 application domain example.

Domain Example

Air Warfare Operational Overview

Air warfare is defined in Joint Department of Defense publications as "the detection, tracking, destruction, or neutralization of enemy air platforms and airborne weapons, whether launched by the enemy from air, surface, subsurface, or land platforms." In an air warfare mission, the Air Warfare Commander (AWC), also known as the Area Air Defense Commander (AADC) for joint operations, is responsible for the development and distribution of an Area Air Defense Plan (AADP). The AADP, which contains the campaign plan and pre-planned responses used in dealing with the enemy air threat, is sent via teletype as a standard formatted military message called the Operational Tasks (OPTASK) Air Defense (AD), to all of the commanders in the battle group and subordinate air defense units, both afloat and ashore. The other significant report promulgated throughout the battle group is the OPTASK Link, which specifies the data link (communication) procedures within the battle group. Upon receipt, the individual commanders analyze the OPTASK AD and Link and generate plans for their respective region/sector of concern within the area of operations. Air defense planning also involves the coordination of air, surface, and mobile air defense assets. Decision-makers coordinate the allocation of scarce resources (airplanes, pilots, missiles, etc.) and work to minimize conflicts between competing engagements. This process is known as maintaining situational awareness. One of the main objectives of the AWC/AADC and his subordinates during the contingency is to maintain situational awareness. Table 1 lists the information they must keep track of in order to accomplish this objective.

TABLE 1. Situational awareness description.

Enemy
Locations (latitude-longitude, grid position, etc.)
Resources (troops, aircraft, tanks, artillery, etc.)
Status (in garrison, deployed, etc.)
Possible actions (attack, defend, reinforce, withdraw)
Friendly
Locations
Resources (platforms)
Status (combat ready, deployed, inside the continental U.S. [INCONUS], etc.)
Control measures (fire support coordination lines, restricted fire areas, phase lines, etc.)
Planned actions (e.g., OPTASK AD, pre-planned responses, etc.)
Logistics (Friendly and Enemy)
Locations
Resources (fuel, ammunition, food)

The report generated in conjunction with maintaining situational awareness is called a situation report (SITREP). Currently, this is a voice report that is required once an hour from all warfare commanders in the battle group.

The next section presents suggestions about opportunities for human–computer collaboration in a Littoral Air Defense mission. Some ways that autonomous agents can assist decision-makers in carrying out C^2 activities, such as formulating pre-planned responses and maintaining situational awareness, are discussed.

Agents in a Littoral Air Defense Environment

Picture a littoral air defense environment (operating close to the shore), where the Joint Forces Air Component Commander (JFACC) is responsible for coordinating theatre air defense among Joint and Allied forces. U.S. forces are involved in a major regional contingency located off the coast of California. The commander responsible for air defense is the Area Air Defense Commander, and is located ashore in an underground command center collocated with the Combined Forces/Joint Task Force Commander. Now we consider some of the specific tasks that agents could be assigned to assist decision-makers in the context of a littoral air defense mission. The AADC's first task will be the formulation of the pre-planned responses contained in the OPTASK AD. To accomplish this, the geographical constraints of the battle space and the evaluation of the enemy and assessment of its capabilities must be considered. The constraints of geography in the battle space must be considered because the contingency is located in confined waters. The battle space may be defined as a conceptual bubble around a friendly force in which a commander feels comfortable in detecting, tracking, and engaging threats before they can pose a significant danger to his vital units/defended asset list. Assume the commander is also constrained by physical "borders," such as reefs or shallows, or territorial borders such as the 12-mile limit, in the positioning of surface-to-air missile picket ships or screening platforms. These factors further reduce the reaction time allotted to any threat that does materialize. Agents with expert knowledge of the specifics of the topology of this region could take the initiative, generate potential plans for attack/defense, and present them to human decision-makers for acceptance or rejection. Another task that must be accomplished is the generation of the OPTASK Link message. Currently, the OPTASK Link report is prepared manually, using a chart and cross-referencing the communication protocols for each asset in the battle group to come up with the list of who can talk to whom. Clearly, this is a cumbersome task that could be automatically handled by an agent that could simply retrieve the necessary information, cross-reference it, and produce a report in a fraction of the time. Upon completion, the agent could present the OPTASK Link to the user for transmission.

Some tasks that agents could perform to help decision-makers maintain situational awareness include keeping track of both friendly and enemy logistics (see Table 1) and monitoring weather conditions. For example, an agent might be assigned the task of keeping track of how many missiles the enemy has. Agents that have access to knowledge about enemy order of battle, (the list of enemy assets) could recommend the optimum shot and determine vulnerabilities. Weather data should be updated periodically, a task that could be performed by a monitoring agent assigned to that particular type of information. For example, if an agent detects an approaching storm, it would then know to advise the decision-maker to suspend air operations temporarily. The agent would also check to ensure that the ship's fuel level was not less than 50%. If the fuel level was less than 50%, action would need to be taken. Fuel level seems like a small detail, but the consequences of a ship running out of fuel and not being able to refuel could be disastrous. Consider that decision-makers are already under a large amount of stress in a contingency, and that declarative memory power is reduced in such a situation. The commander has already been advised to know the enemy capabilities, which involves the analysis of all the ships, aircraft, and submarines that could be encountered. Clearly, this is not a trivial task because it involves the ability to commit a large amount of information to memory. Agents with expert knowledge can provide platform-specific guidance when the need arises, thereby reducing the chances of error in decision-making. There is no reason why a decision-maker should have to keep track of and remember these kinds of details when agents, which are independent of reactions to stress, can assist.

CONCLUSION

The need for automating methods of accomplishing military C^2 activities is critical in today's military mission planning and execution operations. This paper presented some suggestions on the types of tasks autonomous agents operating within C^2 application environments could best perform. These tasks could best be performed in a littoral air defense environment and include assisting decision-makers in maintaining situational awareness, keeping track of both friendly and enemy logistics, monitoring weather conditions, providing information about the geographical constraints of the battle space, and gathering data on the communication protocols for each asset in the battle space and producing a report. Agents need to maintain a minimal degree of autonomy to be of maximum use to decision-makers involved in performing their mission-related C^2 activities. For example, agents, unlike human decision-makers, can keep track of vast amounts of information and do not experience stress in crisis situations. Thus, agents with expert knowledge of enemy capabilities and enough autonomy to determine a need for action could provide platform-specific guidance, thereby reducing the chances of errors in decision-making.

Future research is required to establish the degree to which agents should remain autonomous when acting as planning and decision aids for military decision-makers. Additional research is also needed to prove that the tasks identified in this paper are the types of tasks best suited to agents operating in C^2 application environments.

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